Bulletin No. 113

Second Edition, revised
May, 1935

COMMONWEALTH OF PENNSYLVANIA

DEPARTMENT OF INTERNAL AFFAIRS
Thomas A. Logue, Secretary

TOPOGRAPHIC AND GEOLOGIC SURVEY

George H. Ashley, State Geologist

PENNSYLVANIA GEOLOGY SUMMARIZED

By
Bradford Willard

Excursion of the third annual Field Conference of Pennsylvania geologists

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INTRODUCTION

The purpose of this bulletin is to provide our science teachers and ther interested Pennsylvanians with basic geologic information in general and n Pennsylvania in particular. For this purpose the bulletin is divided into wo parts. The first part deals with the outstanding principles of the science; he second summarizes the geology of the State. It is the intention of the ennsylvania Topographic and Geologic Survey in collaboration with the Pennsylania Department of Public Instruction to conduct from time to time geologic ield trips at various appointed places in the State. These trips are designed rimarily for teachers of science, but attendance of anyone interested will be elcome. This bulletin serves as an introduction to such excursions.

PART I

BASIC PRINCIPLES OF GEOLOGY

Geology is the study of the earth, particularly the earth's crust. eology is not so much one, distinct science, as a group of closely related ciences. It is unnecessary to define or even mention all of these branches, ut we should have a basic conception of the more important ones and likewise nderstand some of the terms that are in common use among geologists.

The most obvious branch of geology is physiography (or geomorphology). t is an amplification of the physical geography of our school days, for it describes the surface features of the earth, its mountains, plains, valleys, treams, lakes and oceans and tries to understand the origin of these features. hysiography treats of the agencies of nature which modify the earth's surface, ost spectacular of which are moving air (wind), water (currents and waves) and ce (glaciers). Many other chemical as well as physical forces change the andscape. Thus, weathering and erosion or rock destruction and removal respectively may be physical or chemical. Physiography is simply geology in action. From the surface characters of the earth we may turn to the composition of its crust.

Mineralogy, as its name implies, is the study of minerals. Despite their common occurrence, a good definition of a mineral is hard to write, but we may look upon them as inorganic substances (formed independent of life) which occur in nature (this eliminates inorganic products of the chemical laboratory) and usually are crystalline in form. Many minerals, particularly those in part or wholly metallic, are of value to man and are mined as ores. There are also nonmetallic earth-products such as coal, petroleum and limestone which are indispensable to civilization. The study of the occurrence and the search for these substances is termed economic geology. When one or more minerals form an appreciable portion of the earth's crust, the aggregate is called a rock; and the branch of geology which deals with the origin, character and composition of rocks is called petrology.

Rocks are of three great classes or groups distinguished according to their mode of origin. They vary greatly in physical and chemical character We have been familiar from childhood with stories of volcanic eruptions in which streams of melted rock called lava flow from crater-topped mountains, bringing desolation to any living thing in their courses. Cold, solidified lava exemplifies a large and diverse group of rocks which have similarly cooled and solidified from a molten, fluid, hot state. This group includes such common examples as granite, some of the "trap" rocks of commerce, and pumice stone. Because such rocks are "fire-born" they are called igneous rocks. Igneous rocks are usually even grained with little or no banding of their crystalline, mineral constituents. When the minerals that compose them can be seen, we find them scattered helter-skelter through the mass. But even the hardest granite may weather to sand and mud. We may see this process going on in ledges exposed to the wind and the rain, the frosts of winter and summer suns. This mud and sand, transported elsewhere, become sediments. When laid down in the beds of streams or lakes or the ocean bottom these sediments may in time be hardened into sedimentary rocks. The sedimentary rocks are the second great class. They are usually recognized by their bedded or stratified habit, each bed commonly composed of grains derived from older, broken-up rock There are many kinds of sedimentary rocks; we need mention only four: (1) shale, indurated (hardened) mud, (2) sandstone made up of cemented sand grains, (3) conglomerate which is consolidated gravel, and (4) limestone, a rock consisting largely of carbonate of lime ($CaCO_3$). Limestone, unlike the other thre kinds of sedimentary rocks, is not formed of fragments of older rocks, but consists of material derived by solution from weathered, older rocks. Circulating water under favorable conditions is an important dissolving agent. From such solution dissolved carbonate of lime may eventually be precipitated. The third and last class of rocks is formed directly from either the igneous or sedimentary groups by a process of change brought about chiefly by the application of heat and pressure. Because of having undergone such a metamorphosis, this thir class is called the metamorphic rocks. The character of the parent rock may be partly or wholly changed; the altered products include such well-known substances as marble, serpentine and slate. Metamorphic rocks are often foliated, that is, they split into thin layers which are in no way related to stratification. Close examination may show that the minerals of these rocks are aligned in rows, layers, or bands parallel to the direction in which the rock breaks (called rock cleavage).

We saw that the metamorphic rocks owe their origin largely to the effect of forces acting upon other, older rocks. The study of these forces is called dynamic geology. This teaches us that rocks may be folded and broken in almost any conceivable manner. Such displacements are called geologic structures. Their study is structural geology. Of the many kinds of structures recognized, we may confine ourselves to two general types. Where the rocks are bent the curved portion becomes a fold. If the rocks break and adjacent parts move in relation to one another along the fracture, we speak of such a structure as a fault. Figure 1 illustrates the commonest kinds of folds and faults.

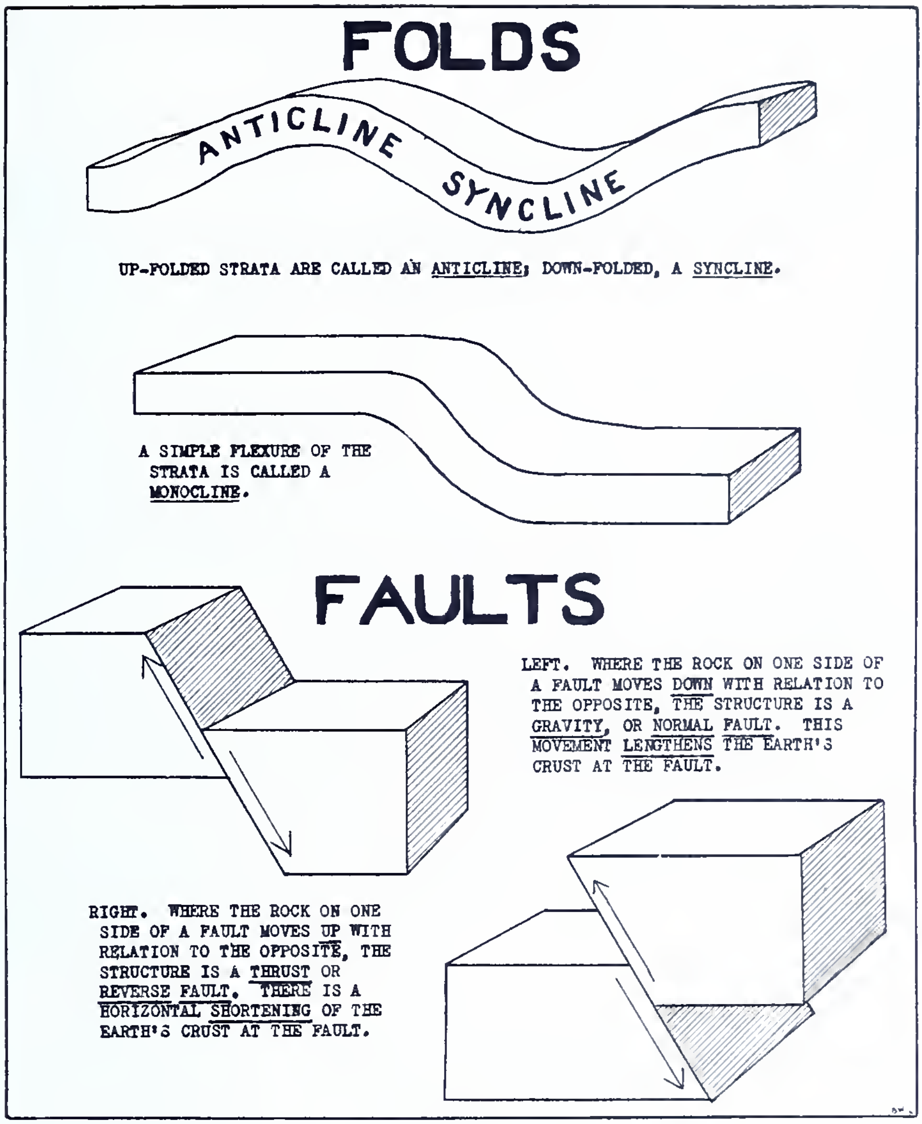

FOLDS
ANTICLINE
SYNCLINE
UP-FOLDED STRATA ARE CALLED AN ANTICLINE; DOWN-FOLDED, A SYNCLINE.
A SIMPLE FLEXURE OF THE STRATA IS CALLED A MONOCLINE.
FAULTS
LEFT. WHERE THE ROCK ON ONE SIDE OF A FAULT MOVES DOWN WITH RELATION TO THE OPPOSITE, THE STRUCTURE IS A GRAVITY, OR NORMAL FAULT. THIS MOVEMENT LENGTHENS THE EARTH'S CRUST AT THE FAULT.
RIGHT. WHERE THE ROCK ON ONE SIDE OF A FAULT MOVES UP WITH RELATION TO THE OPPOSITE, THE STRUCTURE IS A THRUST OR REVERSE FAULT. THERE IS A HORIZONTAL SHORTENING OF THE EARTH'S CRUST AT THE FAULT.

Figure 1. Geologic structures.

The study of the sedimentary rocks involves other branches of geology. Stratigraphy and sedimentation treat of their origin and history. Sedimentary rocks contain remains of the plants and animals which lived in the region when a particular deposit was made. Such remains are chiefly hard parts of organisms preserved more or less intact. They are called fossils. Fossils are absent from igneous rocks; no life could have existed in those molten masses. They are very rare in metamorphic rocks; for, even were the parent rock a sediment, the very processes which metamorphosed it tended simultaneously to obliterate all signs of life. Fossils are of many sorts and tell such significant stories of the past life on the earth that they have been called "the documentary evidence of evolution". The science which treats of ancient life on the earth is called paleontology.

Through paleontology and stratigraphy we study earth history or historical geology. Because the fossil-bearing strata were deposited one upon another, the lower ones are the oldest and contain the remains of the more primitive life forms. Where vast thicknesses of sediments have accumulated, we are sometimes able to observe the entire succession if the rocks have been folded or faulted, raised and dissected by erosion, as in our mountainous regions.

Earth history bears analogies to human history. Both have their modern, medieval and ancient divisions, and in each the ancient history is preceded by a long, perhistoric interval whose beginning is lost and whose events are obscurely known. Both human and earth histories have had their times of tranquility and of upheaval and revolution. We see in each a succession of ruling dynasties of the living which rise, flourish and fall before their successors. A major division of earth history is spoken of as an *era*. Each era is represented by vast thicknesses of sedimentary rocks enclosing fossil remains of distinctive, contemporaneous life forms. Because of these remains the eras are given names indicating their dominant life forms. These Psychozoic and Cenozoic eras are comparable to modern history of man, and the Mesozoic and Paleozoic respectively to medieval and ancient histories. The Proterozoic and Archeozoic eras are analogous to human prehistoric time. Each era is separated from the adjacent by times of *geologic revolution*. A geologic revolution is not like the sudden overthrows of human history, but is an infinitely long interval. Then mountain making took place as the crust was here and there thrown into folds. Igneous rocks rose from below and cut through the sediments to escape at the surface; or, invading those same bedded rocks below the surface, wrought metamorphic changes in them. Each revolution is a time of accelerated evolution. With surface alterations come climatic changes and consequent extinction of some and adaptation of other races of plants and animals to the new environments. The eras are themselves chronologically divided into *periods* each represented by its own succession of rock groups and formations called a *system*. We need not trouble ourselves with the origin of the period names, beyond stating that they are usually taken from some locality where rocks of the corresponding system are characteristically developed. In the strata of each system are buried fossils, some at least of which represent kinds of life which flourished only during the corresponding period. By their distinctive fossils the rocks of different ages may be recognized over wide areas. Such diagnostic fossils are called *guide* or *index fossils*. The periods are separated by disturbances, analogous to but less consequential and shorter lived than the revolutions. The succession of periods and eras has been tabulated in the *geologic timetable*.

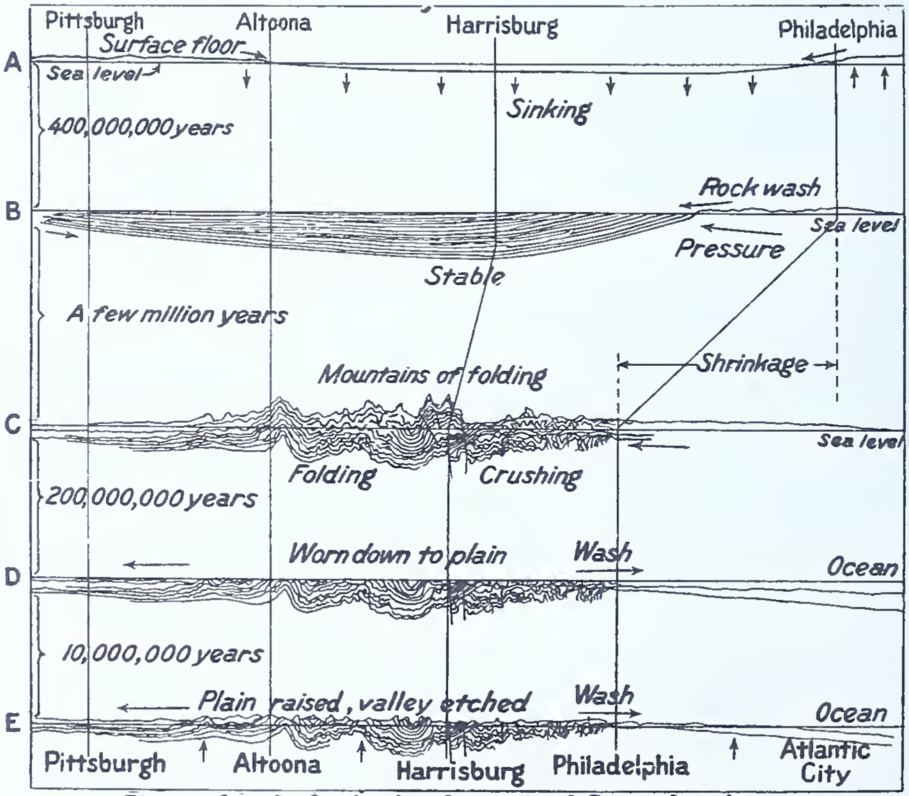


Figure 2. Geologic development of Pennsylvania.

ABBREVIATED GEOLOGIC TIMETABLE

PSYCHOZOIC ERA --- the present*	AGE OF MAN
Cascadian Revolution	
CENOZOIC ERA Quaternary (Pleistocene or glacial) period* Tertiary Period*?	AGE OF MAMMALS AND FLOWERING PLANTS
Laramide Revolution	
MESOZOIC ERA Cretaceous Period* Jurassic Period Triassic Period*	AGE OF REPTILES AND EVERGREEN TREES; FIRST BIRDS AND MAMMALS
Appalachian Revolution	
PALEOZOIC ERA Permian Period* Pennsylvanian Period (coal)* Mississippian Period* Devonian Period* Silurian Period* Ordovician Period* Cambrian Period*	AGE OF HIGHER INVERTEBRATES. FIRST FISHES, AMPHIBIANS, REPTILES AND LAND PLANTS APPEAR
Killarney Revolution	
PROTEROZOIC ERA*) ARCHEOZOIC ERA*?) - - - - - - - - - - - - - - - - - -	(AGE OF LOWER (INVERTEBRATES

*Represented in Pennsylvania by recognized rocks.

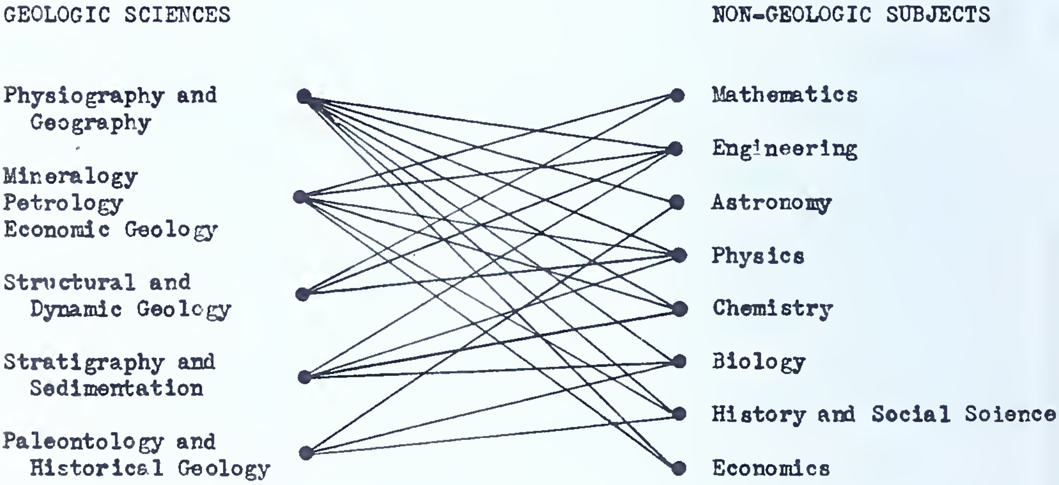
Besides working out the geologic time divisions, historical geology as another important function. It tries to picture the physiography and geo- raphy of the ancient world. We have learned that our mountains may occupy egions of ancient sea bottoms; and vast, shallow seas once flooded large parts f the continents. Fossils of marine shells are known from the high Alps while he teeth and bones of land mammals have been dredged from the present sea loor far from land.

"There rolls the deep where grew the tree.
Oh, earth what changes hast thou seen!
There where the long street roars has been
The stillness of the central sea."

Historical geology is intimately connected with the questions of the age f the earth. We cannot here discuss the methods whereby chronologic data are ob- ained, nor is it germane to enumerate the lengths of the several eras and periods. uffice it to say that these are far from being of uniform length; for the entire ost-Mesozoic time, for example, is approximately of equal length to the rdovician period alone of the Paleozoic Era. Some suggestion of the immensity f geologic time may be gathered if we note merely that the Cenozoic Era began bout 60,000,000 years ago, the Mesozoic some 200,000,000 years ago, and he Paleozoic Era dawned a little over half a billion years before the present. The portion of known geologic time prior to the Cambrian period (spoken of collectively as the Pre-Cambrian) is longer than all the succeeding eras combined. From the foregoing summary of basic, geologic principles, we must admit that geology is complex. It is for this very reason closely related to other sciences.

Some appreciation of the intimacy of such relations may be had if one observes the list of non-geologic studies which are found today in the college curricula prescribed for students of geology. They include such subjects as chemistry, physics, biology, mathematics, engineering and economics. Conversely, the interests of many fields of modern science and other branches of study interfinger with geology. The following "spider-web" diagram illustrates a few such interrelations.

GEOLOGIC RELATIONSHIPS

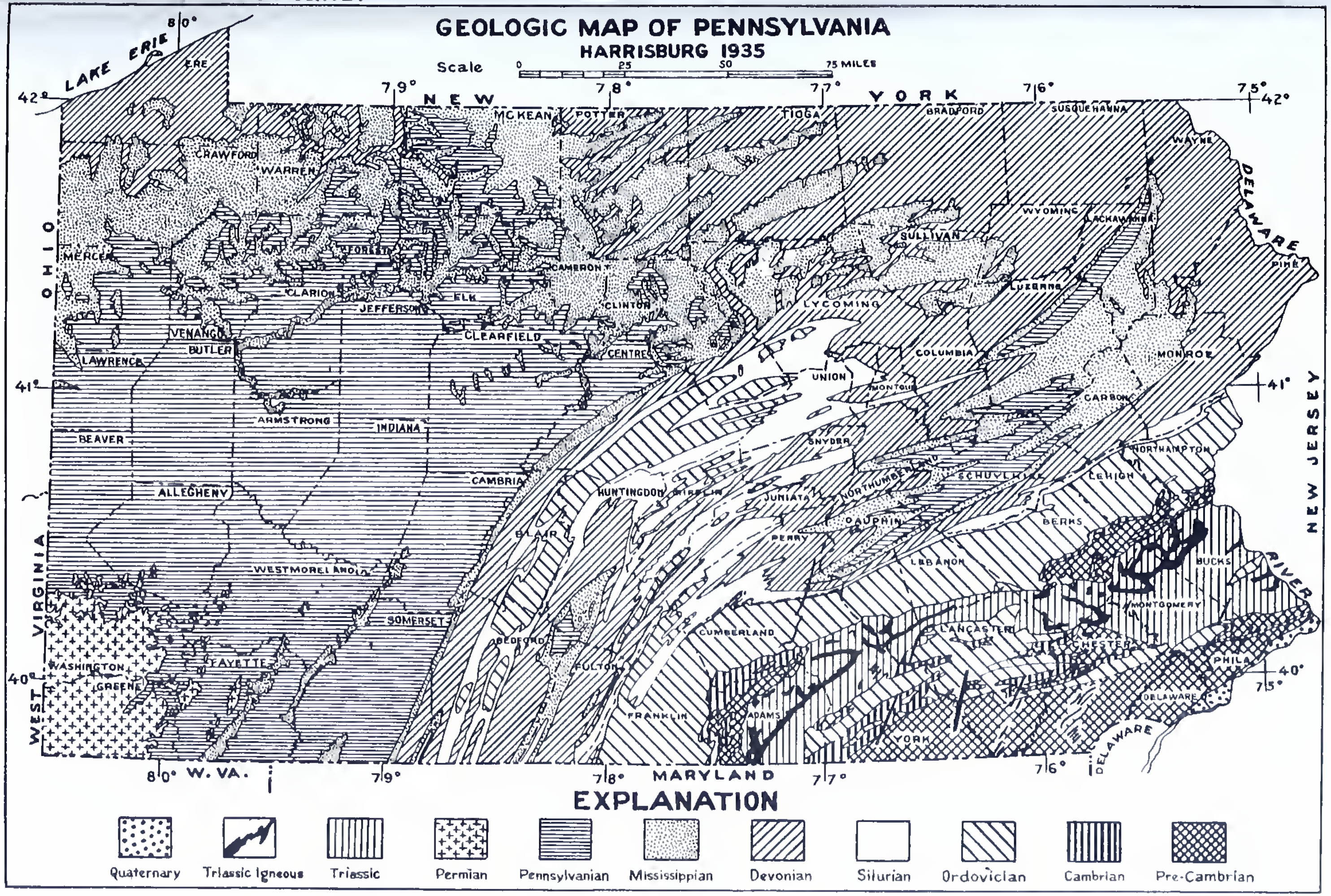

GEOLOGIC SCIENCES
NON-GEOLOGIC SUBJECTS
Physiography and Geography
Mineralogy
Petrology
Economic Geology
Structural and Dynamic Geology
Stratigraphy and Sedimentation
Paleontology and Historical Geology
Mathematics
Engineering
Astronomy
Physics
Chemistry
Biology
History and Social Science
Economics

PART II

THE ROCKS OF PENNSYLVANIA

As we turn from the geologic resume of Part I to the geology of Pennsylvania, we are confronted with a story so long and ramified that an attempt even to summarize it thoroughly would require far more space than can be here allotted. We must confine ourselves to describing the age and character of the larger stratigraphic units, to defining the principal surface features, and to telling concisely the geologic history of the State.

Geologic systems in Pennsylvania. Pennsylvania, though comparatively poor in igneous and metamorphic rocks, possesses widespread sedimentary formations thousands of feet thick and assignable to at least ten systems. All of these usually continue to regions beyond the borders of the State. The succession may be visualized as layer upon layer of rock spread one above another over a greater or less part of the State. Folding, tilting, faulting and uplift, followed by deep cut erosion, have exposed the older beds. Because the intensit



GEOLOGIC MAP OF PENNSYLVANIA
HARRISBURG 1935

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of these processes decreases in a northwesterly direction, it may be said that in general as we traverse Pennsylvania from the southeast toward the northwest we encounter, with few exceptions, successively younger rocks.

In the extreme southeastern portion of Pennsylvania in southeastern Bucks County and extending across Philadelphia, Delaware, Chester, and southern Lancaster and York counties, is a band of ancient, crystalline (that is, chiefly metamorphosed) rocks. There is some disagreement among geologists as to just which system or systems are represented here, the difficulty being in part due to lack of fossils. Probably some of these formations belong to the older Paleozoic systems (Cambrian and Ordovician), but others are doubtless still more ancient and may be assigned to the Pre-Cambrian as among the oldest rocks of the State. Unquestioned Pre-Cambrian rocks occur also in the core of South Mountain through southern Northampton, Lehigh and Berks counties, in Adams County, and at a few other places.

Sandstones and other sediments of Cambrian age have been recognized in narrow bands from southern Bucks County to Adams County and again about the flanks of the South Mountains. The great limestone belts in the Lehigh and Cumberland valleys and also isolated areas of these same rocks in Centre, Huntingdon, Blair and Bedford counties are in part Cambrian in age but chiefly belong to the Ordovician system. The slates of Lehigh and Northampton counties and, westward, the contemporaneously formed shales above the limestone just mentioned are also assigned to the Ordovician. With few exceptions, our Cambrian and Ordovician rocks are deficient in fossils.

Stretching southwestward across the State from the Delaware Water Gap is First or Kittatinny Mountain, which is composed of very hard Silurian sandstone and conglomerate. These same rocks are responsible for many of the long, even-crested, mountain ridges that zigzag through central Pennsylvania. Additional Silurian rocks overlie these ridge makers. Because they are of softer materials they usually underlie valleys which parallel the ridges. Overlying the Silurian rocks are the thick sandstones and shales and a few thin limestones belonging to the Devonian system. These are found everywhere separating the Silurian strata from the formations of the Mississippian system which immediately underlie our coal measures. They extend from the Upper Delaware Valley southwestward into central Pennsylvania, next to the terrain occupied by the Silurian system. Both the Silurian and Devonian strata are as a rule highly fossiliferous, in sharp distinction from the Cambrian and Ordovician, but throughout all four of these systems the fossils are nearly all those of marine invertebrates.

The Mississippian, Pennsylvanian and Permian systems collectively are sometimes referred to as the "Carboniferous", a convenient term when details are unessential. The name comes from the fact that these systems include the chief coal-producing beds of the world. Unlike the preceding systems, which are mostly marine sediments, the "Carboniferous" rocks of Pennsylvania are principally fresh-water beds laid down on the continent inland from the sea. They consist for the most part of gray sandstones, shales and conglomerates; and the middle portion (Pennsylvanian system) contains those extensive coal beds for which our Commonwealth is justly renowned and for which reason its name is applied to this division. Throughout these rocks of late Paleozoic age the commonest fossils are the remains of land plants. The "Carboniferous" marks the close of the Paleozoic sequence, but younger rocks are known in Pennsylvania.

Across the southeastern region from Bucks to Adams County is a band made up of thousands of feet of beds of sandstone, shale and conglomerate, most of which are red. These are the Triassic strata and like the "Carboniferous" were deposited in fresh water, but their red color and the absence of coal imply that somewhat different but not fully understood climatic conditions prevailed in Mesozoic than in late Paleozoic time. Fossils are scarce, but plant impressions and foot tracks of reptiles, the dinosaurs, are occasionally found in the shales. Mesozoic rocks other than the Triassic are not surely known in Pennsylvania unless we except small patches of supposed Cretaceous ediments in Montgomery and Chester counties (not shown in Figure 2). No sure ertiary rocks are known, but the closing event of the Cenozoic era, the great uaternary (or Pleistocene) ice invasion of North America, is recorded in ennsylvania in thick, ice-laid deposits of unconsolidated mud, sand and oulders and in loose sediments left by water running out from the melting ice. hese are confined chiefly to the northeastern and northwestern corners of ennsylvania. A small area of marine sand and gravel of Pleistocene or later ge belonging to the Atlantic coastal plain sediments occurs in the region of hiladelphia.

Except for the metamorphic rocks mentioned in southeastern portions, ll of our formations so far described are sedimentary. But igneous rocks are ecognized. Ancient ones cut into the Pre-Cambrian and some of the older aleozoic formations as if crustal cracks had opened and let imprisoned lavas ell up through the sediments. Far younger, are many bodies of igneous rock, alled "trap", which cut through the Triassic red beds in all directions and t every angle and even extend far beyond their limits into older terrain.

Physiographic features. Northeast-southwest trending mountains reolve the surface features of our State into three clearly defined regions hich are in turn composed in part of lesser units. These features are usually he direct result of geologic structures, but some depend also upon the kinds f rock from which they have been etched. Still other factors have helped to odify the surface expression.

Northwest of a gently sinuous line drawn roughly from Wayne County to omerset County is the Appalachian Plateau. It is a land characterized by high, lat-topped divides separated by steep-sided valleys in which flow deeply enrenched streams. In the northern part of this region which was glaciated, the ffect of the ice is noticed in profoundly altered scenery. The rocks beneath he plateau are a fairly uniform succession of "Carboniferous" and Devonian ediments and have suffered little folding or faulting. Rather, they were raisd bodily to or above their present elevation. It is chiefly because of these wo factors, uniformity of sediments and the horizontal attitude of the strata hat the high plateaus are what they are today.

Immediately east and south of the plateau country is a region in harp contrast with the foregoing. This is the broad band of long, narrow ountain ridges and intermontaine valleys known as the Ridge and Valley Section hich crosses the State from the south-central border nearly to the northeast orner. Intense crumpling of the rocks, which are of many kinds of sediments f unequal hardness, was followed by uplift. Subsequent erosion, cutting down oft beds into valleys, etched out the hard strata as ridges.

Southeast of the Ridge and Valley Section is a region of low mountains, road valleys and rounded hills. Immediately adjacent to the mountainous area ies the Appalachian Valley Section which also runs diagonally southwest-northast from Franklin County to Northampton County. It is the great limestone valey and ties in with the Shenandoah Valley. The true Appalachian Mountains of he Southern Atlantic States are represented in Pennsylvania by a small, mounainous patch in eastern Franklin, Cumberland and western Adams counties and a econd, similar area extending east from Reading to the Delaware River. Southast of the Appalachian Valley and Mountains is the Triassic Lowland consisting f small ridges and valleys underlain by the red, Triassic sediments (see igure 3). The remainder of the southeastern corner of Pennsylvania is made up f narrow limestone valleys and the low hills of the Piedmont region. Along he extreme eastern edge of the Piedmont, a narrow strip of Coastal Plain is ontinuous with that prominent feature of the Middle Atlantic States.

Geologic history. Because we are now familiar with the salient feaures of the succession of the geologic systems and with the physiographic spect of Pennsylvania, we may turn to a condensed description of how these ings came to be. As little is known of the Pre-Cambrian events of Pennsylania, we shall begin our story of the geologic history with the Cambrian

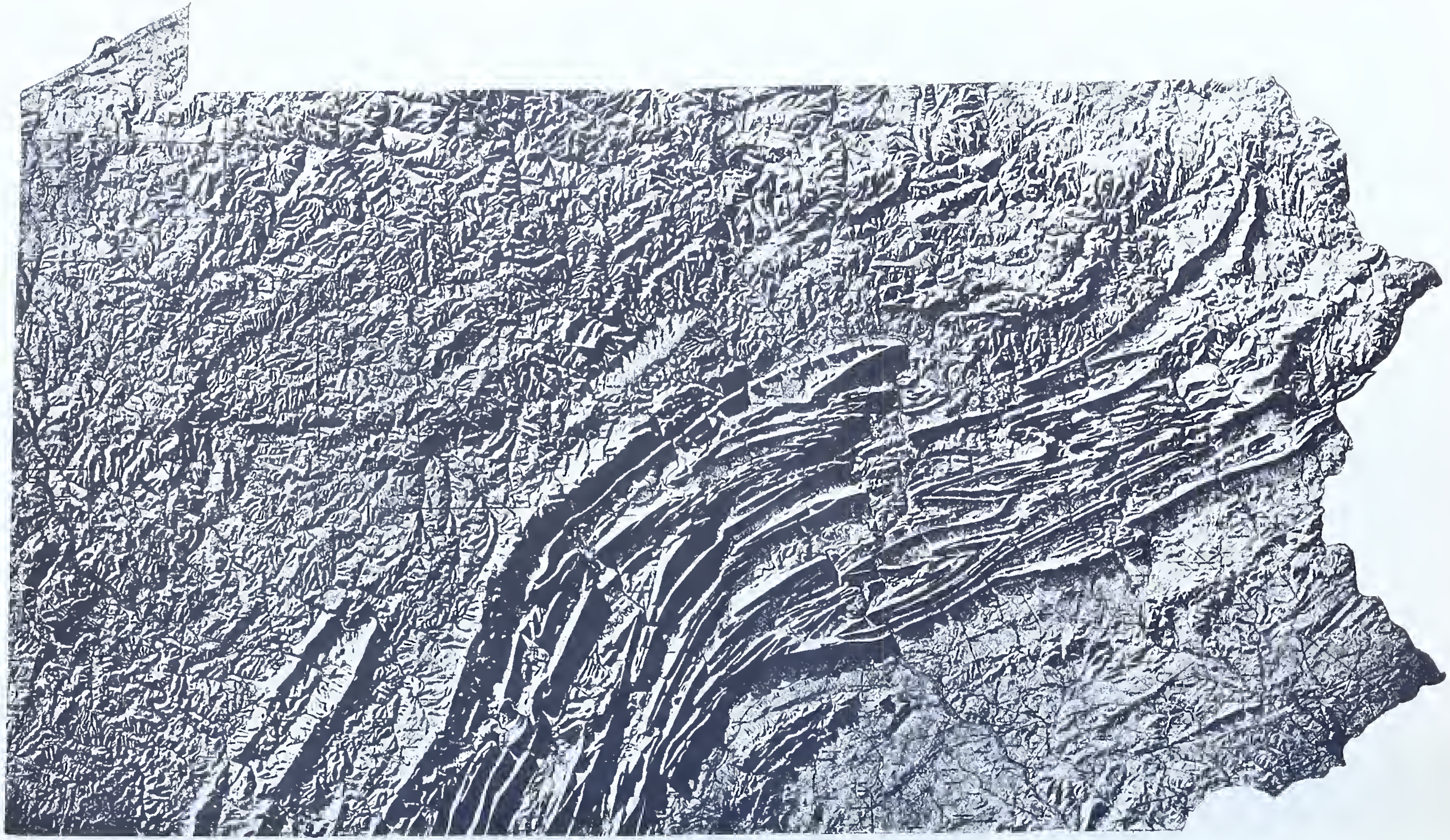

Figure 3. Relief map of Pennsylvania.

period and interpret our story from what we can see in the rocks of the State.

During much of Paleozoic time the general relations of land and sea in the eastern part of the United States were nearly opposite to those of today. Southeastern Pennsylvania was then part of the border of a great, eastward-extending, continental land mass, Appalachia, composed of Pre-Cambrian, metamorphic and igneous rocks. Its western shore crossed southeastern Pennsylvania; and, westward thereof, a vast sea spread into the interior of North America. Along the coast of Appalachia in Cambrian time were sandy beaches. Farther out from shore (to the west) were laid down muds and limy oozes. In Ordovician time the sea spread farther eastward, overwhelming the earlier Cambrian beaches and covering many of the areas of ancient crystalline rocks of Appalachia. Thousands of feet of lime carbonate now seen in the great limestone valleys were deposited. The limy beds were followed by hundreds or thousands of feet of mud destined in part to become the slate of eastern Pennsylvania. The Ordovician ended in a time of change. The ancient land rose and the seas withdrew northwestward. The Ordovician and Cambrian sediments were squeezed as by a force exerted from the southeast. The muds, limestones and sandstones suffered changes and, in the east, were folded. Upon these beds were spread a thousand or more feet of debris washed into the borders of the sea from the newly raised land to the east. These coarse sediments became the Silurian sandstones and conglomerate of Kittatinny Mountain and other ridges of central Pennsylvania. After the first uplift, comparative quite continued during Silurian and Devonian times. Much of southeastern Pennsylvania probably remained dry land, while over the rest of the State a thick succession of sandstones, shales and an occasional thin limestone accumulated. Most of these beds formed in shallow water. Because their aggregate thickness is thousands of feet, we assume that the ocean bottom gradually subsided as the sediments accumulated.

Toward the end of the Devonian came renewed uplift of the eastward landmass, Appalachia, so that the quickened (steepened) streams of that region flowing westward to the interior sea carried in a tremendous quantity of material which brought the ocean bottom up to sea level and created much dry land. The succeeding "Carboniferous" sediments piled up on this new made land from which the sea had been excluded. It was a region of plentiful water supply where grew the dense coal-forming forests. The story of the origin of coal in ancient peat swamps is too well known to require a digression here; rather, we should continue our historical review. The uplift noted in "Carboniferous" times was the Appalachian Revolution which closed the Paleozoic Era. Besides actual uplift, lateral pressure was again put upon the sediments by forces acting northwestward, just as if Appalachia had been shoved against them. The weak rocks buckled and broke, producing those familiar folds and faults of our mountains and valleys bordering the Appalachian plateaus on their eastern side. When pressure was released, the crust toward the east collapsed or subsided in a long trough across southeastern Pennsylvania. Into this valley, streams brought sediments which piled up to thousands of feet in thickness in Triassic times. Eventually, outpourings of lava cut through these strata.

Since the Triassic, Pennsylvania has undergone certain physiographic changes, but there has been little sedimentation because during much of the time the land has stood relatively high, and erosion has continued. The extensive areas of folded and subsequently uplifted Paleozoic rocks underwent long continued wearing down until, by late Tertiary time, the surface approximated a plane near sea level. Such a surface is called a peneplane. Beneath it lay the folded roots of former mountains. Renewed elevation and differential erosion of alternately hard and soft, folded beds toward the close of Tertiary time etched out our mountains of today. An exception is the accumulation of glacial débris in the north. In glacial times, thick ice sheets crept south into northeastern and northwestern Pennsylvania. Melting away, they left deposits of fine and coarse rock fragments, many of which spread southward by streams. Regions of both folded and flat-lying rocks through uplift and erosion have been variously carved into mountain and valley, plateau and ravine.

Before we close, let us glimpse for a moment the history of living things as shown by the fossils in Pennsylvania's rocks. Had we no other proof of organic evolution, one could hardly fail to see the evidence of unfolding life even in our incomplete succession. The Pre-Cambrian rocks are devoid of fossils in Pennsylvania, but some marble of this age in Northampton County carries graphite (carbon) flakes. So far as we know, any considerable amount of this material can so occur only as a result of life processes, even though metamorphism has obliterated the original form and structure of the organisms. The Cambrian rocks contain the borings of such low organisms as "worms", and remains of a few primitive shell fish and crustaceans. Higher types of these same kinds of animals occur in the Ordovician beds. Our Silurian rocks are crowded with a swarm of all sorts of marine invertebrates, and in Perry County actual remains of fish have been found, the oldest backboned animals in Pennsylvania so far recorded.

The Devonian rocks carry much the same kinds of fossils as do the Silurian, but fishes are commoner, more specialized. In Devonian shales in Susquehanna County have been found tiny, five-toed foot tracks believed to be the oldest evidence of land-going, backboned animals yet known in the world. Amphibians left their bones and tracks in our "Carboniferous" strata in western Pennsylvania. The Triassic contains occasionally footprints of small, primitive dinosaurs. Finally, in cave deposits have been unearthed remains of Quaternary mammalian and bird bones which show a very different faunal assemblage from that of our present woodlands, for they include such beasts as the southern peccary and the wooly mammoth of the north. We find no satisfactory and accepted trace of man antedating the Indians, but as such remains are reported from other parts of North America, who knows when such may turn up in Pennsylvania?

No greater service to geology could be performed by the layman or amateur geologist than for him to call the attention of the professional geologist or paleontologist to such finds as he thinks worth while. The ancient land tracks of Devonian backboned animals just mentioned were found by a nonprofessional worker. What can you discover? The Pennsylvania Topographic and Geologic Survey at Harrisburg stands ready to help you and to answer your questions. Do not hesitate to use this service; it is freely at your disposal.

REFERENCES

As a supplement to the foregoing condensed accounts, the following references are suggested. They should also prove useful on field trips.

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*Obtainable from Division of Documents, Department of Property and Supplies, 10th & Market Streets, Harrisburg, Pa. (Stamps are not accepted.)

For those interested in a particular locality in Pennsylvania or a distinct phase of Pennsylvania geology, reference should be made to the reports of the Second Pennsylvania Geological Survey, which are out of print but on file in most large libraries of the State, and to publications of the present Pennsylvania Topographic and Geologic Survey, a list of whose available publications may be obtained free upon request.

GENERAL OUTLINE FOR FIELD TRIPS

I. Physiography.

- A. Weathering of rocks.
  - 1. Agents.
    - a. Physical.
    - b. Chemical.
  - 2. Products.

- B. Removal of products of weathering; erosion.
  - 1. Work of moving air, water or ice.

- C. Physiographic features, identity and origin.
  - 1. Mountains and valleys.
  - 2. Plains and plateaus.
  - 3. Streams, lakes, and other water bodies.
  - 4. Caves and other features.

II. Mineralogy and Petrology.

- A. Minerals.
  - 1. Kinds, characteristics, occurrences.
  - 2. Ores and other economic mineral products.

- B. Rocks.
  - 1. Kinds, characteristics, occurrences.
    - a. Igneous.
    - b. Sedimentary.
    - c. Metamorphic.

III. Geologic structures.

- A. Folds.

- B. Faults.

IV. Paleontology and Historical Geology.

- A. Fossils.
  - 1. Occurrence, kinds, significance.

- B. Rock systems.
  - 1. Systems present.
  - 2. How identified.
  - 3. Relative age and importance in Pennsylvania.

TE: Information regarding the field trips may be obtained from either the Pennsylvania Topographic and Geologic Survey or Wm. H. Bristow, Pennsylvania Department of Public Instruction, Harrisburg, Pennsylvania.